THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

APRIL, 1957

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VOLUME 30 NUMBER 4

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Effects of Neutron Irradiation on Metallic Materials

A. H. COTTRELL: 'Effects of Neutron Irradiation on Metals and Alloys.'
Metallurgical Reviews, 1956, vol. 1, Pt. IV, pp. 479-522.

This is one of the monographs now being regularly published in this journal, under the sponsorship of the Institute of Metals. The aim of these monographs is to present a critical survey of knowledge which may be regarded as covering all major developments to a selected date, and constituting a starting point for study of later progress in the respective fields of knowledge. The individual reviews are prepared by specialists, in the subject, and are supported by extensive but selected bibliographies of authoritative literature.

This review covers certain aspects of 'radiation damage', i.e., effects which can be produced in solids by the action of high-energy radiations such as are released in nuclear disintegrations. The scope of the survey is clearly delimited: it covers neutrons and metals, excluding ionization effects in solids (because electrons in metals are immune to radiation damage). It therefore does not deal with the effects of radiation on the optical, electrical and paramagnetic properties of ionic, covalent and semiconducting solids, or with the chemical damage produced in organic molecules by ionizing radiations. Attention is directed to other surveys which are relevant to aspects of the subject excluded from the present review.

Although the discussion is thus strictly limited in scope, it covers what is of greatest interest to the metallurgist, i.e., the behaviour of metals and alloys under irradiation in a nuclear reactor.

Section I of the survey is introductory.

Section II explains how the damage originates from the collision and absorption of neutrons by atomic nuclei.

Section III describes the behaviour of the fast ions, produced from these neutron encounters, as they penetrate the surrounding material and knock large numbers of atoms out of position.

Section IV compares the estimated amount of damage with measured values, showing that much of the damage disappears very rapidly.

Section V discusses the later stages of the annealing of the damage, in which the displaced atoms gradually migrate back into lattice positions under the action of thermal agitation.

Section VI reviews various metallurgical effects which result from the fact that during both the formative and the annealing stages of the damage the atoms are shuffled about on their lattice sites, e.g., changes in diffusion coefficient and phase changes in alloys.

Section VII deals with a particular effect observed in uranium, called radiation growth.

Sections VIII, IX and X are concerned with effects on the mechanical properties of metals and alloys, occurring either during or after irradiation.

Section XI covers effects due to formation of chemically new atoms in metals by nuclear transmutations, in particular, swelling and disintegration phenomena caused by separation of insoluble gases.

Section XII contains brief mention of some effects of irradiation on the resistance of metals to corrosion.

The review is supported by a *bibliography* of 93 items.

Electrical Resistance and Structure of Thin Films

R. B. BELSER: 'Electrical Resistances of Thin Metal Films before and after Artificial Ageing by Heating.'
Jnl. Applied Physics, 1957, vol. 28, Jan., pp. 109-16.

An extensive literature, over the past hundred years, has established the fact that natural or artificial ageing brings about changes in the electrical resistance of thin metal films and that these changes reflect alterations in structure within the films.

The author of the present paper studied the electrical resistance of thin films of twenty-four metals deposited on glass substrates (near room temperature) by evaporation, sputtering or electroplating: the films investigated included nickel deposited by all three methods. Measurements of electrical resistance were made before and after artificial ageing by heating in vacuo. It was shown that thin metal films as usually deposited appear to be in a state of strain not associated with the corresponding bulk metals as they crystallize from the melt. The application of heat energy to the films promotes removal of the strains, removal of adsorbed or occluded gas, and growth of the crystallites of the film. These concurrent effects reduce the resistance of the films. Changes in optical properties of the films also occur on heating.

Corrosion Fatigue: Monograph

P. T. GILBERT: 'Corrosion Fatigue.'
Metallurgical Reviews, 1956, vol. 1, Pt. III, pp. 379-417.

It is noted in the introduction that, as Gough pointed out some years ago, fatigue and corrosion fatigue cannot be regarded as two separate and distinct groups of phenomena, and although this

division is useful and generally practicable, it cannot be justified on scientific grounds. For the purpose of the present review, however, it is necessary, in the interests of space, to make this arbitrary distinction. No attempt is therefore made to review most of the voluminous data obtained from tests carried out in air, by what are generally classed simply as 'fatigue tests'.

The scope of the respective sections of the review is indicated below:

Brief History of Corrosion Fatigue
from 1917, when a paper by Haigh brought the subject into prominence. The most recent comprehensive review was published in 1932, and the present writer therefore makes little detailed reference to papers before that date, but refers to all important literature published between 1932 and 1939, and deals mainly with papers later than 1939.

Previous General Accounts of Corrosion Fatigue

Definition of Corrosion Fatigue

Factors Involved in Corrosion-Fatigue Testing
Magnitude and type of applied stress, nature of stress cycle, temperature of test, nature of the environment, shape and size of specimen, metallurgical nature of the specimen and its history, surface condition.

Corrosion-Fatigue Test Methods

Characteristics of Corrosion Fatigue

Fatigue Tests carried out in Air and in Inert Environments

Effect of Variations in the Corrosive Environment
Influence of oxygen, various corroding agents, stress range, time, number of cycles and other test variables.

Quantitative Corrosion-Fatigue Data for Various Materials,
including iron, mild steel, and low-alloy steels; stainless irons and steels; copper and copper alloys; nickel and Monel; aluminium and aluminium alloys; lead and lead alloys.

Relationship of Corrosion-Fatigue Failures to Microstructure

Electrochemical Aspects of Corrosion Fatigue

Corrosion Fatigue in Practice

Protection against Corrosion Fatigue,
by means of protective metallic or non-metallic coatings, by the introduction of surface compressive stresses, by nitriding, etc., and by use of inhibitors.

The review is supported by a *bibliography* of about 170 references.

Sorting of Scrap Metals

E. SCHEUER: 'The Sorting of Scrap Metals and Alloys.'
Metallurgical Reviews, 1956, vol. 1, Pt. III, pp. 339-78.

Brief discussion of considerations involved in sorting of metals and in the selection of methods for specific purposes, followed by a detailed review of methods and instruments employed for identification and separation of metallic materials on the basis of their respective chemical, physical, mechanical and other properties. A section of the review is devoted to practical methods which are in large-scale use for sorting of various types of metal scrap. The monograph is well illustrated and is supported by a *bibliography* of about 80 references. An appendix contains a table giving details of chemical tests which may be employed for identification of aluminium alloys of various types.

NICKEL

Extraction of Nickel by the Ammonia Pressure Leach Process

J. P. WARNER: 'Nickel Recovery at Fort Saskatchewan.'
Industrial Chemist, 1956, vol. 32, Sept., pp. 359-68.

The author is Head of the Economic Services Department, Sherritt Gordon Mines Limited, Chemical Metallurgical Division, Fort Saskatchewan, Alberta. He gives in this article an account of the development of the process used for nickel extraction, with the essential features of the chemistry on which it is based, and subsequently describes, with flowsheet, the various stages of the process and the plant used.

See also—
'Hydrogen Reduction Nets Nickel.'
Chemical Engineering, 1957, vol. 64, Jan., pp. 194-7.
Illustrated flow sheet of the process.

Casting Properties of Nickel

See abstract on p. 55.

Corrosion Fatigue: Monograph

See abstract on p. 48.

Effect of Mechanical Deformation on the Magnetic Properties of Nickel and Nickel-Iron Alloy

H. DIETRICH and E. KNELLER: 'The Influence of Plastic Deformation on the Mechanical Properties of Single Crystals of Nickel.'
Zeitsch. f. Metallkunde, 1956, vol. 47, Oct. and Nov., pp. 672-84, 716-28.

I. The law of approach to magnetic saturation was experimentally studied at room temperature, as a function of plastic deformation of single crystals of nickel of varying orientation. Comparative investigations were made on recrystallized polycrystalline nickel.

II. The influence of plastic deformation, on intensity and temperature-dependence of coercivity, was studied on rod-shaped single-crystal specimens of nickel, over the range −200°C. to the Curie point (360°C.). In this section of the work also comparison was made with polycrystalline nickel.

Influence of Hydrogen Adsorption on Electrical Resistance of Nickel Films

J. H. SINGLETON: 'Hydrogen Sorption and the Para-hydrogen Conversion on Evaporated Nickel Films.'
Jnl. Physical Chemistry, 1957, vol. 60, Jan. 8, pp. 1606–11.

Changes in electrical resistance of an evaporated nickel film, resulting from adsorption of hydrogen, were studied at −78°C. Three distinct processes were observed. Initially hydrogen is irreversibly adsorbed, causing a drop in resistance. This is followed by a second stage in which there is reversible adsorption over a pressure range from 10^{-5} to at least 600 mm., causing an increase in resistance, and this adsorbed hydrogen is responsible for the parahydrogen conversion. A third type of sorption occurs rapidly at room temperature and to an appreciable extent at −78°C., decreasing the resistance of the film and poisoning the catalyst with respect to the parahydrogen conversion. The limitations involved in obtaining evaporated metal films of reproducible properties are discussed.

Electrical Resistance and Structure of Thin Films

See abstract on p. 48.

Nickel Catalysts

J. E. BENSON and T. KWAN: 'Kinetics and Mechanism of the Hydrogenation of Cyclopropane over a Nickel-Silica-Alumina Catalyst.'
Jnl. Physical Chemistry, 1957, vol. 60, Jan. 8, pp. 1601–5.

Hydrogenation of cyclopropane was investigated by a static method, over a commercial isomerization catalyst, between 56° and 100°C. Adsorption isotherms were determined for hydrogen between 0° and 400°C. and for cyclopropane at 0° and 32·3°C. The reaction of the catalyst with carbon monoxide was also investigated, and its chemical nature is briefly discussed.

R. L. MOTARD, R. F. BURKE, L. N. CANJAR and R. B. BECKMANN: 'The Kinetics of the Catalytic Hydrogenation of Benzene on Supported Nickel and Nickel-Oxide Catalysts.'
Jnl. Applied Chemistry, 1957, vol. 7, Jan., pp. 1–14.

In the development of a pilot plant for studying reactions involving heterogeneous catalysis a nickel catalyst was selected for the initial study. This paper reports investigation of the hydrogenation of benzene in a fluidized reactor, using nickel and nickel oxide supported on silica gel for the reaction

$$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$$

Temperatures were 150°–220°C. for the nickel-oxide experiments and 220°–275°C. for nickel. Pressures were 25–100 p.s.i.g. and molal ratios of hydrogen to benzene ranged from 0·5 to 3·9.

Electrodes for Arc Welding of Nickel

See abstract on p. 57.

Resacetophenone Oxime as Indicator in Determination of Nickel

K. S. BHATKI: 'Volumetric Determination of Cyanide and Nickel with Resacetophenone Oxime as an Indicator.'
Analyst, 1957, vol. 82, Jan., pp. 24–6.

Using resacetophenone as internal indicator, a solution of cyanide can be standardized against a standard nickel solution prepared from extra-pure nickel ammonium sulphate. It is shown that in a similar manner an indirect determination of nickel can be made, thus avoiding the use of a more expensive reagent such as silver nitrate, which is employed in most of the established methods for estimation of cyanide.

Determination of Nickel in Iron and Steel

See abstract on p. 60.

Determination of Boron in Nickel

R. C. CHIRNSIDE, H. J. CLULEY and P. M. C. PROFFITT: 'The Determination of Traces of Boron in Nickel.'
Analyst, 1957, vol. 82, Jan., pp. 18–24.

It has recently been established that the presence of traces of boron in nickel used for the anodes of thermionic valves can, in some cases, lead to low emission. The need has thus arisen for a method for the determination of boron, at levels of a few parts per million, in nickel. The present paper describes an analytical procedure developed for this purpose.

The sample is made the anode of a mercury-cathode electrolysis apparatus, resulting in simultaneous dissolution of the sample and deposition of dissolved nickel into the mercury. The boron in the electrolyte is then determined spectrophotometrically by the curcumin method. Full working instructions are given.

In the samples examined during development of the method boron contents of 2–23 p.p.m. were found in specimens of thermionic-anode nickel. By dissolving away only a surface portion of the samples it has been found possible to show that a concentration of boron occurs at the surface of the nickel.

Although the procedure described was devised specifically for estimation of boron in nickel, the authors suggest that it may also be applicable to metals other than nickel, provided that the main constituents of the sample can be removed from solution by electrolysis over a mercury cathode.

Reactions between Nickel and Sodium Hydroxide

D. M. MATHEWS and R. F. KRUH: 'Reactions in Sodium Hydroxide–Nickel System.'
Industrial and Engineering Chemistry, 1957, vol. 49, Jan., pp. 55–8.

The many potential applications of hydroxides in high-temperature chemical engineering have recently

focused attention on reactions liable to occur between metals and hydroxides at elevated temperatures. In particular, there is interest in the behaviour of nickel in contact with sodium hydroxide in connexion with the use of the metal in containers. The experiments described in this paper fall into two groups:—

(1) those made to determine whether an equilibrium gas pressure is obtainable,

(2) a study of material balance among reactants and products.

The authors make the following summary of their observations:—

'The substantial attack of nickel by sodium hydroxide in vacuum begins at about 600°C.

'There is virtually no evidence that a steady hydrogen pressure is attained at a given temperature.

'Molten sodium hydroxide creeps along the surface of the vessel containing it. This phenomenon is a source of great experimental difficulty.

'The series of equations that is believed to represent the reactions in the system NaOH-Ni under continuous evacuation is:—

'Attack of nickel:

$$2NaOH + Ni \rightarrow NiO + Na_2O + H_2 \qquad (1)$$

'Formation of nickelate:

$$2NaOH + NiO \rightarrow Na_2NiO_2 + H_2O \qquad (2)$$

'Reduction of sodium (following hydrogen evolution):

$$Ni + Na_2NiO_2 \rightarrow 2NiO + 2Na \qquad (3)$$

'The existence of a compound, Na_2NiO_2, was demonstrated. This substance occurs as clear green crystals of needle-like habit and is rapidly hydrolyzed to sodium hydroxide and nickel hydroxide.

'In each of the reactions postulated a gaseous product is removed as it is formed. Certainly equilibrium in equations 1 and 3 lies far to the left, and an estimate of the standard free energy change indicates this to be true for equation 2. It is concluded that the reactions in vacuum are driven by removal of gaseous products and that if the system sodium hydroxide-nickel were isolated no net reaction would occur. For equation (1) the following would be expected:—

$$2NaOH + Ni \rightarrow Nio + Na_2O + H_2$$
$$NiO + H_2 \rightarrow H_2O + Ni$$
$$H_2O + Na_2O \rightarrow 2NaOH$$

i.e., nothing.'

ELECTRODEPOSITION AND OTHER COATING METHODS

Effect of Tank-Lining Materials on Electrodeposited Nickel Coatings

J. EDWARDS: 'The Effect of Certain Constituents of Tank Linings on Nickel Electrodeposits.'

Electroplating and Metal Finishing, 1957, vol. 10, Feb., pp. 41-3.

This article is based on the results of research carried out by the British Non-Ferrous Metals Research Association, the results of which were earlier communicated to the members of the Association in the form of a confidential memorandum.

Rubber or plastic linings of tanks, pumps, filters and pipes afford possible sources of contamination of nickel-plating solutions, and defects in nickel coatings have frequently been attributed to this cause. Impurities are most likely to be introduced when the linings are new and it is therefore often recommended that a newly-lined tank be soaked in dilute acid solution for a day or two before being taken into service. Such treatment does not, however, remove all extractable contaminants from the lining, and impurities may continue to be leached out for some time under normal working conditions. The presence of the contaminants is particularly likely to become apparent in deposits made after the baths have been out of use for even a short time.

Suspicion that contamination is occurring may be checked by making a plating test on a small sample of the solution before and after storing it for some days in contact with a specimen of the lining which is suspect. In most cases a Hull-cell test is adequate, but in some instances ductility or stress measurements may be desirable if the mechanical properties of the deposit are in question. Such tests are strongly recommended as routine before a new lining is put into service.

The tests reported in this paper were made to determine which of the constituents of the various types of rubber and plastic used for linings have any deleterious effect on nickel-plating solutions. A detailed account is given of Hull-cell tests made on samples of Watts-type solution and of typical proprietary bright-nickel solutions, all of which had been in contact with representative rubber and plastic materials used for lining electroplating equipment. The conclusions drawn are summarized below:—

'The Watts-type dull nickel solution was unaffected by contact with pure vulcanized rubber with one accelerator (tetramethylthiuram disulphide) or with one anti-oxidant (acetone-aniline). Tests of a sample of rubber produced using only these two additions confirmed that it was inert towards an organic bright-nickel solution: the rubber appears suitable as a lining material, having the requisite physical and mechanical properties.

'Tests made on other rubbers containing addition agents which were known to have deleterious effects on nickel-plating solutions showed that the state of combination of these substances within the rubber sheet did not prevent their being leached out to some extent. The contamination of the solution which resulted was only slight with some of these rubbers and these types might, therefore, provide tank linings tolerable in some circumstances, particularly if they were given a thorough preliminary soaking in dilute hydrochloric acid before being allowed to come into contact with the plating solutions. Nevertheless, it seems inadvisable to use them in view of the fact that rubber containing

tetramethylthiuram disulphide and acetone-aniline is completely inert in nickel-plating solutions and is apparently satisfactory in other respects.

'Plasticizers used in P.V.C. sheet were shown to have only a slight effect on the appearance of an organic bright-nickel deposit. Rigid P.V.C. was quite harmless.'

Levelling: Mechanism and Measurement

J. D. THOMAS: 'Levelling: Definition, Measurement and Understanding.'

43rd Ann. Technical Proceedings, Amer. Electroplaters' Soc., 1956, pp. 60–6.

Practical interest in the levelling characteristics of plating solutions is increasing as demands for uniform bright surfaces become more exacting and precise.

Levelling is defined 'as the ability of a plating bath to produce deposits relatively thicker in small recesses and relatively thinner on small protrusions, with an ultimate decrease in the depth or height of the small surface irregularities.' The author introduces his report with illustrations of deposits in which varying degrees of levelling have been achieved.

This paper describes a method for evaluating the levelling power of plating solutions, using precision reference specimens of controlled dimensions, the electrodeposited coatings on which are measured by the Surfindicator (roughness-measuring instrument), by the interference microscope, and by cross-sectioning.

Experimental study of a bright nickel-plating solution showed that the primary cause of levelling is the combination of organic agents added to the electrolyte. In the presence of such addition agents, the degree of levelling is controlled by the operating conditions: increased levelling is obtained with an increase of current density, lowering of temperature, and agitation.

The author discusses possible explanations of the mechanism of levelling: such factors as concentration gradients, thickness of diffusion film, relative migration rates for the addition agents and the depositing ion, and the specificity of adsorption on various portions of the surface are discussed.

Current Distribution and Levelling in Electrodeposited Coatings

D. G. FOULKE and O. KARDOS: 'Current Distribution on Microprofiles, I.'

43rd Ann. Technical Proceedings, Amer. Electroplaters' Soc., 1956, pp. 172–80.

O. KARDOS: 'Current Distribution on Microprofiles, II', *ibid.*, pp. 181–94.

The first of these papers attempts to explain the phenomena of cathodic microthrow and levelling, by the assumption that the effective thickness of the diffusion layer is larger for microrecesses than for micropeaks. The second paper is designed to give the theoretical justification for that assumption, and to discuss its consequences in greater detail. A large part of the supporting data relates to observations made on electrodeposited nickel coatings, prepared from various solutions and under a wide range of operating conditions.

Nickel Plating of Jet-Engine Parts

R. W. MOELLER and W. A. SNELL: 'Limitations of Nickel in Jet-Engine Parts.'

43rd Ann. Technical Proceedings, Amer. Electroplaters' Soc., 1956, pp. 230–3.

The main purpose of using nickel coatings in jet engines is as a substitute for cadmium coatings, for preventing corrosion of parts operating at temperatures above the melting point of cadmium. In addition, there is some possibility that electroless nickel coatings, which give good coverage on complex shapes, may be useful for plating of components working at lower temperatures.

Two major problems are involved in the use of nickel coatings: (1) dimensional tolerances, which call for coatings in the range 0·0003–0·0005 in. thick, and (2) the prevalence of high operating stresses in the engine parts, which intensifies the importance of residual stresses caused by nickel plating. To meet the requirements of satisfactory corrosion-resistance and ability to withstand high operating temperatures, using thicknesses of plating within the limits permitted by dimensional allowances, a composite coating of nickel/cadmium has been utilized, but the successful use of such a coating in large-scale design is closely dependent on the quality of the nickel plating. Ideal results, under continuous production conditions, have not yet been achieved.

This paper reports tests on various types of electrodeposited nickel coating, indicating limitations inherent in their use, singly or diffused with cadmium. Solutions of five types were used: Watts (high- and low-chloride), sulphamate (with or without addition of a reagent to induce compressive stress), and electroless nickel (Brenner and Riddell solution). Aircraft-quality steel was used as the basis material, heat-treated to a hardness of Rockwell C 39–40.

Measurements were made, on the respective plated specimens, of residual stress and fatigue endurance, in comparison with the corresponding properties of the unplated steels. Some comparisons were also made of the resistance of nickel- and nickel/cadmium-plated specimens in the salt-spray test, as a function of thickness of coating. It is noted that effects resulting from cracking of a brittle plate at elevated temperatures may also be harmful: typical examples of cracking in electroless nickel coatings are illustrated.

The conclusions drawn from the tests are that four principal factors at present limit the use of plated nickel in jet-engine parts:

(1) Inadequate degree of corrosion-resistance obtainable in nickel deposits sufficiently thin to be acceptable from the standpoint of dimensional tolerance. For some applications this may be overcome by the use of a composite plating such as diffused nickel/cadmium, which gives better resistance to corrosion.

(2) Reduction in fatigue strength of steel resulting from residual tensile stresses introduced by plating with nickel.

(3) Production processing and control difficulties involved in translating laboratory-scale operations into large-scale commercial practice.

(4) Other drawbacks such as the brittleness of electroless nickel deposits. Development of more ductile deposits should further the application of this type of coating.

Electroless Nickel Plating

H. NARCUS: 'Improved Techniques for Electroless Nickel Plating on Non-Conductors.'

43rd Ann. Technical Proceedings, Amer. Electroplaters' Soc., 1956, pp. 157–61.

This paper comprises a critical commentary on some of the practices which have been used in plating by the electroless method, together with recommendations for improvements, based on the author's experience.

The first comment is that in recent literature too little attention has been given to methods for preparing the surfaces of non-conductors for coating by the electroless process, although it is on this step that much of the success of the process depends. A description is then given of the essential stages of improved techniques which have been developed by the author for plating non-conductors. Among the major points made are the following:

(1) *Cleaning*. A chemically clean surface is imperative: condition may be tested by absence of water-breaks. Ceramic, glass and quartz may be prepared by treatment in soak cleaners used for steel, and synthetic detergents and emulsion cleaners have also been used with good effect. Plastics may usually be cleaned in solutions used for non-ferrous metals.

(2) *Roughening*. Roughening (de-glazing, de-polishing) is essential in order to promote adhesion. The method employed varies with the material being plated: the table below shows procedures recommended for typical materials.

(3) *Sensitizing*. The best-known sensitizing solution is stannous chloride, used either as a solution of this salt alone in water or alcohol, or with the addition of hydrochloric acid. In some cases a wetting agent is added.

The author recommends, however, a solution which has proved satisfactory in preparing non-conductors for plating with copper or silver, and which, when used in preparation for electroless nickel, gave improved results (more rapid coverage and adhesion). The composition is given below.

Stannous fluoborate concentrate (47%)	15–20 g.
Fluoboric acid (42%)	50 cc.
Hydrofluoric acid (52%)	10 cc.
Triton N.E. (1% by wt. soln.) ..	10 cc.
Water	1,000 cc.

Operated at room temperature; immersion time 2 min., followed by cold-water rinse and warm-water rinse. It is noted that the solution should be stored in rubber or polyethylene containers.

(4) *Activating*. Palladium chloride is most generally used to produce a catalytic surface for subsequent electroless coating, but the author recommends, as giving better results, a solution containing:

Gold chloride (50%)	0·01–0·1 g.
Water	1,000 cc.

Operated at room temperature; immersion time 2 min., followed by cold- and warm-water rinsing.

This solution, in addition to giving better coverage

Roughening Procedures

Material	Method	Alternative Method
Ceramics	$HF-H_2SO_4$ (*a*)	..
Glass	$HF-NH_4F$ (*b*)	.. Liquid honing with vapour-blast equipment
Quartz	$HF\ NH_4F$ (*b*)	..
Thermoplastic resins	$K_2Cr_2O_7-H_2SO_4$ (*c*) ..	.. Grit blasting (220-grain aluminium oxide or G80 grit)
Thermosetting resins	Hydroquinone-pyrocatechin-acetone mixture (*d*)	Grit blasting (220-grain aluminium oxide or G80 grit)

Key

(*a*) 500 cc. H_2SO_4
500 cc. HF
250 g. CrO_3
4000 cc. H_2O
(One-minute treatment)

(*b*) 150 cc. HF
50 cc. NH_4F
4000 cc. H_2O
(One-minute treatment)

(*c*) 100 cc. H_2SO_4
15 g. $K_2Cr_2O_7$
50 cc. H_2O
(Two-minute treatment)

(*d*) 400 cc. Hydroquinone
100 cc. Pyrocatechin
4000 cc. Acetone
(Three-minute treatment)

and adhesion of the nickel coating, has various other advantages, which are noted in the paper: among these are the ease of removal of the gold-chloride solution by rinsing, thus minimizing contamination of the nickel-plating solution and lengthening its life.

(5) *Electroless Nickel Plating.* Several baths have been employed, with varying success. The author recommends the following composition, as giving the most consistent results, especially in large-scale plating.

Nickel sulphate	35 g.
Sodium citrate	10 g.
Sodium acetate	10 g.
Sodium hypophosphite	15 g.
Magnesium sulphate	20 g.
Duponol C (1% by wt. soln.) ..	10 cc.
Water	1,000 cc.

The addition of brighteners is optional, but if these are required 5 cc. of Harshaw XXX44 and 3 cc. of XXX20 may be employed. The solution is operated at 185°-190°F. (85°-88°C.); initial pH is 5·6-5·8. This bath, which is stated to be less susceptible to decomposition than others tested, deposits 0·0005 in. of nickel per hour.

The second part of the paper details some of the experimental work on which the development of the gold-chloride activating treatment is based, demonstrating the improved results obtained in the final nickel coating, and the wider range of operating conditions permissible with the gold-chloride, as compared with the palladium-chloride, solution.

Electrical Resistance and Structure of Thin Films

See abstract on p. 48.

Electrodeposition of Nickel-Iron Alloys for Magnetic Shielding

I. W. WOLF and V. P. MCCONNELL: 'Nickel-Iron Alloy Electrodeposits for Magnetic Shielding.' *43rd Ann. Technical Proceedings, Amer. Electroplaters' Soc.*, 1956, pp. 215-18.

Starting from information contained in a patent of 1931 covering the electrodeposition of nickel-iron alloys in the form of thin sheet or ribbon, experiments were carried out to determine conditions optimum for electrodeposition of an alloy containing approximately 80 per cent. of nickel, balance iron, of 0·003 in. minimum thickness. The iron content of the solution and operating conditions were varied in a bath of the following basis composition:

	g./L.
$NiSO_4.6H_2O$	218·0
NaCl	9·7
H_3BO_3	25·0
Sodium lauryl sulphate ..	0·42
Saccharin	0·83

pH was 2·7

It was found that deposits of the type required could be obtained from a bath of this composition containing about 1·2 g./L. of iron if ferrous sulphate was used and about 1·6 g./L. of iron if ferrous ammonium sulphate was employed.

The shielding characteristics of electrodeposited material so produced were compared with those of Mumetal, a standard alloy which is widely used in magnetic shields. The results indicated that the electrodeposited 79-21 per cent. nickel-iron alloy has a permeability lower than that of Mumetal in low field ranges, but that its permeability is greater in intermediate and higher ranges. The cross-over occurs at about 0·6 oersted.

Since the shielding properties of the electrodeposited alloy were not satisfactory under all conditions, attempts were made to increase their efficacy by embodying molybdenum in the deposit, but although various molybdenum compounds were used as additions to the nickel-iron bath, satisfactory deposits were not obtained. It is suggested that further work may lead to solutions containing other molybdenum compounds by which deposits of more satisfactory types can be produced.

Gas-Permeability Testing of Corroded Nickel Electrodeposits

D. G. FOULKE and J. M. TOBIN: 'Effect of Corrosion on the Gas-Permeability of Nickel Electrodeposits.' *43rd Ann. Technical Proceedings, Amer. Electroplaters' Soc.*, 1956, pp. 234-8.

The authors open with notes on the essential features of two porosity test methods which have been developed by investigators working under the Research Project Committees of the American Electroplaters' Society: the gas-permeability test (see *Plating*, 1948, vol. 35, p. 917 and 1954, vol.41, p. 469), and a photographic test, developed to overcome certain limitations found in the gas-permeability method.

Previous tests of porosity in relation to gas-permeability had been made on uncorroded electrodeposited nickel, giving ratings designated 'intrinsic permeability' (see *Jnl. Electrochemical Soc.*, 1956, vol. 103, pp. 545-8; *Nickel Bulletin*, 1956, vol. 29, No. 12, p. 208). In these later experiments a comparison was made of the initial (intrinsic) gas-permeability of nickel electrodeposited from various types of bath and of the permeability of the deposits after immersion in 10 per cent. sulphuric-acid solution, or anodic corrosion in 3 per cent. sodium-chloride solution. The observations made demonstrate that consistent results can be obtained by that method, and that there is a definite difference, with reference to permeability to helium, between nickel made by melting and casting and electrodeposited nickel. It was not, however, found possible to correlate the gas-permeability of the thin foils required for such measurements with the generally accepted service corrosion characteristics of electrodeposited nickel coatings. Watts-type and cobalt-nickel deposits, which are normally considered to be more resistant to atmospheric corrosion than organic nickel deposits, showed both a greater initial (intrinsic) porosity and a more rapid increase in porosity under accelerated corrosion tests than that found in the organic bright-nickel deposits.

Radiographic Determination of Porosity in Metal Coatings

F. OGBURN and M. HILKERT: 'The Nature, Cause and Effect of Porosity in Electrodeposits. II. Radiographic Detection of Porosity in Electrodeposits.'

43*rd Ann. Technical Proceedings, Amer. Electroplaters' Soc.*, 1956, pp. 256–9.

Report issued under the aegis of A.E.S. Research Project 13.

Methods which have been proposed in earlier reports, for measurement of porosity, are applicable only to plated coatings after removal from the basis metal. While such procedures have proved reliable and useful, it is not known whether the porosity of adherent coatings is identical with that of coatings stripped from the base.

The first report issued under this Project described a radiographic method which has subsequently been successfully used by other investigators. It comprised plating a radioactive metal over the basis metal and depositing the coating under investigation over the radioactive layer. By placing a suitable photographic film over the plated surface, a radiograph of the porosity could be obtained. The technique described in the present paper eliminates the need for the intermediate layer of radioactive metal which, it is pointed out, could influence the porosity of the coating which is being investigated.

The authors report studies made, by the improved technique, of Watts-type nickel electrodeposits of various thicknesses, on mild steel of thicknesses selected to ensure good radiographs within a reasonable time of exposure. Of the films tested, a fine-grain industrial X-ray type (Kodak Type M) gave the best results. Requirements which must be satisfied by the radioactive materials used as the source of radiation are considered: in the experiments reported radioactive cobalt, nickel and iron were used. Radiations emitted by these metals are tabulated. Apparatus and experimental technique are described, and the interpretation of the X-radiographs is discussed.

Comparison of the results obtained by the radiographic method with attack undergone by identical plated materials subjected to the ferroxyl test, indicates that the ferroxyl reagent creates pores or enlarges pores which initially are too small to be detected by the radiographic test. It is also concluded that the ferroxyl test induces or enlarges pits which may not be detected by the radiographic method. It is thus evident that the ferroxyl solution attacks the nickel coating, but not always to the extent which will result in sufficient attack of the steel basis metal to yield a blue spot. Some comparison was made also between radiographic findings and rust spots developed on nickel coatings exposed to marine atmosphere. The results suggest that although the discontinuities detected by the radiographs are likely sites for rust spots, only a small proportion of the rust spots correspond with radiographic spots, indicating that failures usually occur at points where the radiographs did not detect discontinuities. It must therefore be concluded that either the radiographic method, as at present used, is not sufficiently sensitive to detect most of the pores, or that failure of coatings occurs also through some other mechanism, e.g., local galvanic cells may lead to perforation of the coating. It is possibly significant that the first rust spots appearing on the test panels were not predominantly those corresponding to radiographic spots. Further adaptation of the microradiographic technique appears to be essential before the full potential value of this method can be realized.

Hard Surfacing of Metals: Data Sheet

R. J. FABIAN: 'Hard Coatings and Surfaces for Metals.'

Materials and Methods, 1957, vol. 45, Jan., pp. 121–40. *M. and M. Manual No.* 134.

Covering the nature of the major types of hard coating and surfacing materials, the base materials which can be coated and the thickness ranges in which the coatings can be imposed, hardness of typical coatings, and their principal properties and applications. The forms of coating reviewed include diffusion coatings and heat-treated surfaces, electrodeposited coatings, anodic finishes and sprayed coatings.

NON-FERROUS ALLOYS

Casting Properties of Nickel Alloys

D. R. WOOD and J. F. GREGG: 'The Casting Properties of Some Nickel-base and other Nickel-containing Alloys.'

Brit. Foundryman, 1957, vol. 1, Jan., pp. 2–14.

Fluidity testing of metals and alloys (on which there is an extensive literature) has been based in many cases on measurement of the extent to which the respective materials would fill the cavity of a mould of standard pattern, and in the majority of the investigations a spiral mould has been used, taking the length of casting run as a measure of castability, generally defined as fluidity.

In the work reported in the present paper a modified version of the spiral-mould technique described by Taylor and Rominski* was used, but in these later tests two factors were considered: (1) total length of casting produced in the standard mould (fluidity rating) and (2) percentage of the whole spiral length which satisfactorily reproduced the mould contour (casting quality). This second characteristic is shown to confirm the differences between alloys which, although giving similar fluidity values, show strikingly different amounts of misrunning when cast in similar moulds. (It is noted that the casting quality so assessed is concerned solely with degree of reproduction of mould contour, *not* with quality of surface, which can be profoundly influenced by the composition of the facing sand and by the nature of the mould dressing.)

Green-sand moulds were used throughout the tests, since preliminary tests on green-sand and dry-sand moulds had demonstrated that there was no significant difference in either fluidity or casting

* *see Trans. Amer. Foundrymen's Assocn.*, vol. 49, p. 1.

quality between castings produced by the two methods. The mould and runner systems used, and the experimental technique, are illustrated.

The first part of the paper describes the effects, on fluidity and casting quality, of small variations in the composition of Inconel, a nickel-chromium-iron alloy having valuable corrosion- and heat-resisting properties, but limited castability. Later sections of the report contain results of castability tests on a wide range of nickel-base and other nickel-containing alloys.

Part I. The standard alloy used was of the following composition: carbon 0·1, silicon 0·5, manganese 0·5, chromium 16, iron 7, per cent., nickel balance. The influence of the following modifications was studied:—

Silicon	(1, 2 and 3%)
Manganese	(1·5 and 3%)
Carbon	(0·25%)
Molybdenum	(2·5 and 5%)
Tungsten	(2·5 and 5%)
Niobium	(0·25, 0·5, 0·75 and 1%)
Vanadium	(0·25, 0·5, 0·75 and 1%)
Zirconium	(0·25, 0·5, 0·75 and 1%)
Calcium	(0·3%)
Zirconium	(0·25%) + niobium (0·25%)
Silicon	(3%) + molybdenum (2·5%)
Silicon	(3%) + zirconium (0·25%)

A report is made of the results of the tests on all the modified alloys, and graphs show the fluidity and casting qualities of typical alloys when poured at various temperatures.

It was found that at a given pouring temperature fluidity was not markedly affected by any of the above variations in composition. The greatest degree of improvement resulted from additions of 3% silicon + 2·5% molybdenum, the average increase, over the pouring-temperature range 1475°–1525C°. being about 7 in. in 30 in. (A similar improvement could have been produced in the standard alloy by raising the pouring temperature by about 40C.°) Casting quality was, however, much more susceptible to improvement by variations in composition: in particular, high silicon contents were beneficial and the improvement effected by silicon was confirmed on commercial castings. Only one of the modifications tested, 5 per cent. tungsten, impaired the relatively poor casting quality of the standard alloy.

Part II. Using the procedure described, an evaluation was made of the casting characteristics of other nickel-containing alloys. The types examined were:

Monel, H Monel, S Monel

Nickel

Brightray C, Nimonic alloys 75, 80, 90, D and DS (nickel-chromium-base alloys)

Hastelloy B and C (nickel-molybdenum-base alloys)

H.R. Crown Max and 18-8 chromium-nickel austenitic steels

M.C. 58, (creep-resisting nickel-cobalt-chromium-base alloy).

Nominal compositions of all the alloys are shown and details are given of the preparation of the respective materials, deoxidation treatments, etc. The results of the tests are shown in graphical form, with commentary. Among the general comments are the following:

Monel gave excellent casting quality over a wide range of pouring temperature, and is therefore used as a standard of comparison in recording the results for the other alloys. The fluidity of Monel increased progressively with silicon content, reaching a very high level in S Monel (Si 3·7%). Nickel, of the standard casting composition, had a significantly lower fluidity rating than Monel and at pouring temperatures in the region of 1530° had a castability rating only half as high as that of Monel. The casting properties of Brightray C and Nimonic 75 (both nickel-chromium-base alloys, but varying in silicon, aluminium and other minor-element contents) were practically identical, but Brightray C (higher silicon) was the more fluid of the two. In the range of pouring temperatures used, Nimonic 80 (nickel-chromium-base) was somewhat more fluid than Nimonic 90 (nickel-chromium-cobalt-base), but the casting quality of the latter alloy was better than that of the 80 alloy; in both cases it was of a relatively high order. The influence of silicon content is reflected in the results obtained on Nimonic D and Nimonic DS, where, although the alloys showed similar fluidity characteristics, the casting quality of the higher-silicon type (DS) was better than that of the lower-silicon type. Hastelloys B and C (nickel-molybdenum-iron-base alloys) were both somewhat less fluid than Monel, but the B alloy had a high casting quality, whereas Hastelloy C (containing chromium) had a much lower rating.

Of the austenitic steels, H.R. Crown Max, although considerably less fluid than Monel, showed a marked improvement in casting quality as the temperature of pouring was raised, whereas the casting properties of the 18-8 chromium-nickel steel remained very low at all pouring temperatures. The experimental casting alloy, M.C. 58, was even more fluid than Monel and at pouring temperatures above 1520°C. showed good casting quality.

These tests may be interpreted as indicating that, from a practical standpoint, casting quality is at least as important as fluidity: the criterion of casting quality adopted, although arbitrary, is believed to give results which are directly relevant to sand-casting practice. It may justifiably be concluded that casting quality is less dependent upon degree of superheat than upon chemical composition, and it is probably significant that the alloys showing poor casting quality at pouring temperatures up to 200C°. above their melting points contain chromium and have low silicon contents, whereas the three alloys showing the best casting quality are the silicon-containing 70-30 nickel-copper alloys and high-silicon Inconel.

Although it might be deduced that satisfactory casting properties could be secured in any alloy by pouring at a sufficiently high temperature, there

are strict limitations to this simple solution. Excessively high pouring temperature may lead to metal-mould reaction, gas pick-up, mould wash and other difficulties, and it is therefore necessary to select alloys on a basis of good castability over practical ranges of casting temperature.

Sigma Phase in Alloys containing Vanadium and Nickel

J. B. DARBY and P. A. BECK: 'Sigma Phase in Certain Ternary Systems with Vanadium.'

Jnl. of Metals, 1957, vol. 9, Jan., Sect. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 69–72. T.P. 4373E.

The following ternary systems were studied to determine the boundaries of the sigma phase:

V–Fe–Co
V–Fe–Ni
V–Co–Ni
V–Mn–Fe
V–Mn–Co
V–Mn–Ni

It was found that in all cases the σ phase forms a relatively narrow elongated field in the ternary system, connecting with the binary σ phases. The investigation was carried out by means of microscopical and X-ray examination of alloys prepared by vacuum induction melting in recrystallized alumina crucibles. Full details of preparation of the specimens and of experimental technique are given.

Structure of Molybdenum-Nickel-Chromium Alloys

D. P. SHOEMAKER, C. B. SHOEMAKER and F. C. WILSON: 'The Crystal Structure of the *P* Phase, Mo–Ni–Cr. II. Refinement of Parameters and Discussion of Atomic Co-ordination.'

Acta Crystallographica, 1957, vol. 10, Jan. 10, pp. 1–14.

The determination of the structure of the *P* phase in the molybdenum-nickel-chromium system was part of a programme concerned with the investigation of the structures of some members of a group of binary and ternary alloys of transition metals which had previously been shown to be inter-related in their phase behaviour and probably to be electron compounds related to the sigma phase. The present report is an amplification of information published *ibid.*, 1955, vol. 8, Nov. 10, pp. 734–5: see *Nickel Bulletin*, 1956, vol. 29, No. 1, p. 8.

Corrosion Fatigue: Monograph

See abstract on p. 48.

Royal Mint Report

'Eighty-Sixth Annual Report of the Deputy Master and Comptroller for the Year 1955.'

Published by *H.M. Stationery Office*, 1956; 89 pp. Price 5/-.

The Report includes the usual memoranda and statistics covering silver, cupro-nickel and nickel-brass currency, and information on medals struck at the Mint. The Trial of the Pyx is also recorded, and the Reports from the Melbourne and Perth Branch Mints are included.

Electrodes for Arc Welding of Monel and Nickel

F. A. BALL and D. R. THORNEYCROFT: 'Aspects of the New Monel and Nickel Arc-Welding Electrodes.'

Welding and Metal Fabrication, 1957, vol. 25, Feb., pp. 59–64.

This paper reports tests demonstrating the properties of new types of electrode which have been introduced by The International Nickel Company, Inc., for the welding of overlays of nickel and Monel on the surface of mild steel and for welding the clad side of Monel- and nickel-clad steels. It is anticipated that they will prove advantageous also in welding solid Monel and nickel and in the welding of these materials to steel. The 130-Monel and 131-nickel electrodes (which the new types are intended to replace) have been extensively used for many years for assemblies involving, respectively, Monel and nickel, but it has been appreciated that they were not in all cases suitable for applications in which other metals also are concerned, and for preparation of overlays on steel.

This paper opens with brief notes on the limitations of the 130-Monel and 131-nickel electrodes, and reports at length laboratory tests made to assess the suitability of the new electrodes for the European market.

The examination was divided into four main sections: (1) the welding of overlays on mild steel, (2) the welding of clad steels, (3) the welding of solid Monel and nickel, and (4) hot-cracking tests. In each group of tests direct comparison was made between the 130- and 140-Monel electrodes, and between the 131- and 141-nickel types. Determination was also made of the chemical composition of the deposits, and their structure was examined.

The observations made are considered to justify the following conclusions: 'Most of the shortcomings of the 130-Monel and 131-nickel electrodes have been overcome in the new 140 and 141 series, which will be particularly suitable for preparation of overlays and for welding clad steels. The 140-Monel electrode makes possible the deposition of sound overlays directly onto steel, without need for a preliminary layer of nickel, and such overlays have a high bend ductility. The overlay deposited by the new electrode is appreciably lower in iron than that deposited by the 130-Monel electrode, because the 140 electrode penetrates less deeply into the base metal.

'Better arc control is possible with the 141- than with the 131-nickel electrode and, in consequence, the deposits are more uniform and show greater freedom from slag entrapment. The superiority of the weld surface of the 141-nickel deposit was particularly noticeable in overlays on mild steel and in butt joints in nickel plate.

'Comparison of the compositions of weld metal from the two series of electrodes shows that the new series are appreciably lower in carbon. Coupled with the

presence of niobium, this appears to be the major factor contributing to prevention of hot cracking in Monel deposits when these are high in iron, as in overlays on steel, and in the root run of welds in Monel-clad steel. In the nickel weld metal the lower carbon content results also in greater cold ductility in overlays and in the welds in nickel-clad steel.

'The new electrodes show fewer advantages for the welding of solid Monel and nickel than for deposition of overlays and the welding of clad steels. They are, nevertheless quite suitable for these applications, and for some nickel structures the slightly softer weld metal may be an advantage.'

Although it is appreciated that field experience will be necessary to confirm or modify the conclusions drawn from these laboratory experiments, it is noted that the new electrodes have already been widely tested for normal construction in America, and that the results obtained there have been consistent with those reported in this paper.

Determination of Cobalt in Steels and Nickel Alloys

D. SALYER and T. R. SWEET: 'Determination of Small Amounts of Cobalt in Steels and Nickel Alloys.' *Analytical Chemistry*, 1957, vol. 29, Jan., pp. 2–4.

A method involving cobaltinitrite separation, isotope dilution, and anodic electrodeposition can be used for the determination of small amounts of cobalt in steels and nickel-base alloys. By the procedure described, the time of standing of the cobaltinitrite is reduced to 30 minutes, compared with the 24 hours usually recommended as essential to ensure complete precipitation. The materials on which specimen analyses are reported include a Monel-type alloy, an 18 per cent. nickel nickel silver, a 36 per cent. nickel steel and a nickel-chromium-iron alloy.

NICKEL-IRON ALLOYS

Structure and Magnetic Properties of Permanent-Magnet Alloys during Ageing

E. BIEDERMANN and E. KNELLER: 'Structure and Magnetic Properties of Permanent-Magnet Alloys during Isothermal Precipitation Hardening.

I. Growth of the Particles, Critical Particle Size and Coercive Force. II. The Course of Structural Breakdown and the Significance of these Changes.' *Zeitsch. f. Metallkunde*, 1956, vol. 47, May and Dec., pp. 289–301, 760–74.

I. X-ray and electron-microscope methods were used to study the process of particle growth during isothermal breakdown of several copper-nickel-iron magnet alloys, as a function of time of annealing. The coercive force of the alloys was also measured. A number of observations made confirm work by DANIEL and LIPSON (*Proc. Royal Soc., A.*, 1943, vol. 181, p. 368· 1944, vol. 182, p. 378).

An explanation based on structural condition is advanced to account for the maximum coercive force observed during hardening. Structural breakdown in a copper-nickel-cobalt alloy during hardening was found to be similar to that occurring in copper-nickel-iron alloys, a conclusion contradictory to the findings of earlier investigators.

II. This section reports measurements of the course of saturation magnetization, remanence, magnetic viscosity, electrical conductivity and mechanical hardness, as functions of time of treatment during isothermal hardening of copper-nickel-iron alloys. The authors also discuss the general principles covering the magnetic behaviour of substances which consist of fine ferromagnetic particles in a non-magnetic matrix.

CAST IRON

Resistance of Nickel-Alloy Cast Iron to Corrosion and Abrasion

J. DEARDEN AND J. D. SWINDALE: 'Effects of Alternate Corrosion and Abrasion on Some Ferrous Metals.' *Jnl. Iron and Steel Inst.*, 1957, vol. 185, Feb., pp. 227–34.

The resistance of eleven ferrous materials to corrosion, abrasion and combinations of both effects was determined. The specimens tested included plain and low-alloy steels, and various types of cast iron, including grey and white grades. The corrosion attack to which the specimens were subjected comprised exposure in an industrial atmosphere: at intervals the corrosion products were removed by abrasion.

With the exception of grey cast iron, all the materials showed an increased rate of corrosion with frequency of abrasion: a summary of the observations on the nickel-alloy cast iron is given below.

The three white cast irons (Ni-Hard nickel-alloy cast iron, white iron containing chromium, and chill cast iron) all showed exceptional resistance to abrasion and corrosion or a combination of both. Of all the materials tested, Ni-Hard cast iron was the most resistant to corrosion alone. Under alternate corrosion and abrasion it behaved in a manner very similar to that observed for chilled iron, and was relatively insensitive to frequency of abrasion. Its resistance to abrasion alone is reported as inferior to that of the other two white cast irons.

Determination of Nickel in Iron and Steel

See abstract on p. 60.

CONSTRUCTIONAL STEELS

Hydrogen Embrittlement in Ultra-High-Tensile Nickel-Alloy Steel

E. P. KLIER, B. B. MUVDI and G. SACHS: 'Hydrogen Embrittlement in an Ultra-High-Strength 4340 Steel.' *Jnl. of Metals*, 1957, vol. 9, Jan., Sect. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 106–12. T.P. 4219E.

It is now generally recognized that hydrogen is

frequently responsible for delayed failures encountered in high-strength steels, and that the gas is introduced during cathodic cleaning and plating operations. In the present paper hydrogen embrittlement as promoted by copper plating is compared with that developed by cathodic treatment in caustic soda. The basis steel was nickel - chromium - molybdenum S.A.E. 4340 type, treated to various tensile-strength levels above 200,000 p.s.i. (90 tons per sq. in.). The authors point out that some of the test methods which have been employed for determination of embrittlement are unsuitable: in their own work they employed bend, variable-rate tensile, notch-tensile and sustained-load methods.

In agreement with previous work, it was found that, as determined by static tests, hydrogen embrittlement depended on the rates of strain used. Rate of recovery from hydrogen embrittlement was, however, not the same for the cathodically cleaned and for the plated specimens. Failure in sustained-load tests was shown to result from the development of a surface crack which, through growth, reduces the load-bearing cross section, with consequent increase in the nominal stress on the section, to a value equal to that of the fracture stress.

Temper Embrittlement of Nickel-Chromium Steel

L. D. JAFFE and D. C. BUFFUM: 'Upper-Nose Temper Embrittlement of a Ni-Cr Steel.'

Jnl. of Metals, 1957, vol. 9, Jan., Sect. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 8-16. T.P. 4309E.

In an earlier report information had been given on the isothermal temper embrittlement of a nickel-chromium steel of the S.A.E. 3140 type*. The main attention had then been given to embrittlement at 575°C. and below, but preliminary measurements had indicated that embrittlement at 675°C. was much more rapid than would have been anticipated from observations made at lower temperatures, suggesting the possibility of an upper 'nose' in the time-temperature embrittlement diagram above 575°C.

In the work described in this later paper the same heat of steel was used and the experimental methods adopted were similar to those used in the earlier experiments. All blanks were austenitized for one hour at 900°C. and water-quenched. Embrittlement was then studied as a function of tempering temperatures ranging from 325° to 675°C.: both isothermal and temperature-change treatments were used.

The steel showed two regions of temperature in which brittleness developed rapidly and isothermally. The lower range extended downwards from about 600°C., with most rapid embrittlement at 550°-490°C., and continued to low temperatures, where the change became very slow. The upper range extended from Ae_1 (about 690°C.), where embrittlement was most rapid, and continued downwards, overlapping the lower range. The upper-nose embrittlement also became very slow as the temperature was lowered.

* Carbon 0·38—0·43, nickel 1·10—1·40, chromium 0·55—0·75, per cent.

The report includes considerable discussion of the structural characteristics of the embrittled material. Embrittlement in the lower temperature range was accompanied by rapid grain-boundary attack on etching with ethereal picric acid, and fracture was along austenite grain boundaries. Material embrittled in the upper range was only slowly attacked by the same acid, and fracture was mostly along ferrite grain boundaries. No increase in ferrite grain-size was observed, but it was found that carbide particles grew during treatments in the upper embrittling range. Embrittlement resulting from slow cooling from 675°C. appeared to be associated with the lower temperature range.

See also following abstract.

G. BHAT and J. F. LIBSCH: 'On the Nature of the Embrittlement Occurring while Tempering a Ni-Cr Alloy Steel', *ibid.*, pp. 20-2; T.P.4317E.

This paper also deals with the characteristics of low-temperature and high-temperature embrittlement in S.A.E. 3140 steel. Data are presented to confirm that embrittlement proceeds by one mechanism in the low-temperature range and by another in the higher-temperature region. Low-temperature embrittlement occurring at 925°F. (495°C.) is completely removed by re-heating at 1250°F. (675°C.) for very short times, and has essentially no influence on the subsequent development of embrittlement on prolonged heating at the higher temperature 1250°F. (675°C.). Such behaviour is consistent with either nucleation or growth of a precipitate, and its solution at higher temperature, or with segregation of solute elements to prior austenite grain boundaries and the re-distribution of the solute elements as numerous well-defined ferrite grain boundaries develop with prolonged heating at higher temperatures.

High-temperature embrittlement (1250°F.: 675°C.) appears to be related to a permanent structural change which is continuous with temperature and time. The authors' data show that this structural change, which apparently persists, has a significant influence on the rate and extent of subsequent embrittlement at 925°F. (495°C.). This is consistent with the development of well-defined ferrite grains at 1250°F. (675°C.), their growth with increasing time, and their influence upon distribution of a precipitate or segregate on subsequent re-heating at 925°F. (495°C.). It is suggested that, in view of these observations, retrogression phenomena are not necessary to explain embrittlement, but that the segregation of solute atoms to prior austenite and ferrite grain boundaries may provide a better explanation of the two modes of embrittlement. It is also indicated that an essentially unembrittled state is most nearly obtained by restricting the times of tempering rather than by quenching from an elevated temperature.

Conventional tempering treatment used to obtain an unembrittled condition, ½-1 hr. at 1200°-1250°F. (650°-675°C.), results in a permanent structural change which can affect the rate and extent of subsequent embrittlement at 925°F. (495°C.).

Corrosion Fatigue: Monograph

See abstract on p. 48.

Resistance of Nickel-Alloy Steels to Corrosion and Abrasion

See abstract on p. 58.

Production-Control Analysis in Steel Works

D. MANTERFIELD and W. S. SYKES: 'Production-Control Quantometer for Steelworks Analysis.'
Jnl. Iron and Steel Inst., 1957, vol. 185, Jan, pp. 105–13

The instrument described is a direct-reading spectrometer suitable for routine analysis. The principles of its operation are described and its design and use are illustrated. Iron is used as an internal standard for analysis of steels and the instrument is calibrated against standard samples of known composition.

Results obtained in determination of individual elements (present as residuals or in larger amounts) are demonstrated by reference to analysis of various types of steel. It is shown that the results obtained by the Quantometer are equal in accuracy to those given by chemical methods, and the spectrometric procedure has advantages in speed of analysis. The specification upon which the Quantometer is designed covers determination of P, Si, Mn, Ni, Cr, Sn, Cu, Mo, Al, V, Ti, Pb and B in steels and of SiO_2, Fe, CaO, P_2O_5, MnO, MgO, Al_2O_3 and F in slags and sinters.

Determination of Nickel in Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel. Part 37. Nickel in Iron and Steel.' *B.S.* 1121: Part 37: 1957. Price 2/6.

The methods described in this Standard are of wider application than those covered by B.S. 1121: Part 6: 1948, Method A of which specification is now withdrawn.

Two procedures are dealt with in the present schedule:

Method A, applicable to all nickel contents, in all classes of iron and steel, subject to the qualification that cobalt present in the test solution should not exceed 0·15 g. The sample is dissolved in hydrochloric acid and oxidized with nitric acid, and the nickel is precipitated as its glyoxime complex, from ammoniacal citrate solution.

Method B, which is applicable to low-nickel high-cobalt steel, where the amount of cobalt in the test solution exceeds the limiting value of 0·15 g. specified for Method A. Nickel and cobalt are converted to complex cyanides, the cobalt cyanide is oxidized with hydrogen peroxide to the stable cobalti-form, and nickel is precipitated with dimethylglyoxime, using formaldehyde to decompose the nickelo-cyanide selectively.

In both methods the filtered glyoxime complex is dissolved in mineral acid and nickel is determined by titration with potassium cyanide and silver nitrate.

The specification makes detailed recommendations with regard to the reagents required, sampling, and analytical procedure. Other sections cover standardization of the silver nitrate, calculation of nickel content, and other points significant in relation to accuracy and reproducibility of results.

Determination of Molybdenum in Steels

J. P. MCKAVENEY and H. FREISER: 'Analytical Solvent Extraction of Molybdenum using Acetylacetone.'
Analytical Chemistry, 1957, vol. 29, Feb., pp. 290–2.

Acetylacetone has been found to be a selective extraction reagent for molybdenum in ferrous materials. Molybdenum (VI) is extracted from a 6*N* sulphuric-acid solution, while copper, tungsten and chromium, which normally interfere in the colorimetric procedure for molybdenum, are not extracted at that acidity. After extraction the molybdenum is determined as the thiocyanate.

Typical analyses made by this method, on nine National Bureau of Standards standardized samples, are given to demonstrate the accuracy of the results obtainable. The materials analysed included representative nickel-containing and other low-alloy steels, austenitic stainless steels and ferroalloys.

HEAT- AND CORROSION-RESISTING MATERIALS

Precipitation-Hardening Stainless Steels

G. E. LINNERT: 'Welding Precipitation-Hardening Stainless Steels.'

Reprint of Fourth Adams Lecture to the American Welding Society.

Welding Jnl., 1957, vol. 36, Jan., pp. 9–27.

Precipitation-hardening stainless steels of various types have been developed to meet the demand for materials which will offer the high degree of corrosion-resistance characteristic of the standard austenitic chromium-nickel steels but which, unlike those grades, will be capable of being hardened by heat-treatment. The useful combination of properties producible in the modified stainless steels is leading to their ready acceptance for a wide range of structural and other engineering applications.

As regards composition, these precipitation-hardening steels consist essentially of carefully proportioned amounts of chromium and nickel, with balanced additions of other alloy elements, e.g., aluminium, copper, molybdenum, and titanium, used in various combinations. The lecturer presented a useful annotated summary of data on the compositions and properties characteristic of some typical precipitation-hardening steels already developed: a table containing the essential details is reproduced on page 61.

Study of the welding of these steels has revealed a number of specialized problems resulting from the novel combinations of elements present, and much detailed investigation has been carried out to evaluate the welding characteristics of the respective grades of steel and to determine optimum welding conditions. This lecture is based on investigations in the Armco Research Laboratories: it concentrates on metallurgical conditions encountered in welding precipitation-hardenable stainless steels, using the 17-4 P.H.,

Table I

Precipitation-Hardening Stainless Steels

Grade Designation	Forms Available	Regular Annealing and Hardening Treatments	Typical Chemical Composition							
			C %	Si %	Cr %	Ni %	Cu %	Mo %	Al %	Others %
Group 1—Single-Treatment Martensitic Steels										
Stainless 'W'	Wrought	Anneal 1900°F. (1035°C.) Harden 950°–1050°F. (510°–565°C.)	0·07	—	17	7	—	—	0·2	Ti 0·7
17-4PH	Wrought Cast	Anneal 1900°F. (1035°C.) Harden 900°–1100°F. (480°–595°C.)	0·04	—	17	4	4	—	—	Nb 0·3
Group 2—Double-Treatment Martensitic Steels										
17-7 PH	Wrought	Anneal 1950°F. (1065°C.) Transform 1400°F. (760°C.) Harden 1050°–1100°F. (565°–595°C.) *Alternative Treatment*— Anneal 1750°F. (955°C.) Transform −100°F. (−75°C.) Harden 950°F. (510°C.)	0·07	—	17	7	—	—	1·2	—
AM 350	Wrought	Anneal 1725°F. (940°C.) Transform −100°F. (−75°C.) Temper 750°–900°F. (400°–480°C.) *Double Ageing Treatment*— Anneal 1700°–1950°F. (925°–1065°C.) Age 1350°F. (730°C.) Age 800°–900°F. (425°–480°C.)	0·08	—	17	4	—	2·8	—	—
Group 3—Austenitic Steels										
17-10 P	Wrought	Anneal 2050°F. (1120°C.) Harden 1200°–1300°F. (650°–705°C.)	0·12	—	17	10	—	—	–	P 0·25
3311	Wrought	Anneal 2200°F. (1205°C.) Harden 1200°–1400°F. (650°–760°C.)	0·17	—	22	23	—	—	3·25	—
Group 4—Austenitic-Ferritic Steels										
V2 B	Cast	Anneal 2000°F. (1095°C.) Harden 925°F. (495°C.)	0·07	—	19	10	2	3	—	Be 0·15 Si 3

17-7 P.H. and 17-10 P types to exemplify the points discussed. Throughout the lecture, particular attention is directed to the value of metallographic examination as an aid to solution of welding problems.

The welding characteristics of the individual steels are considered in close detail. Each of the sections includes fundamental and practical information, which can be utilized not only in the welding of these materials, but also as a basis for further development in the welding of precipitation-hardening steels in general. The scope of the subject matter relating to the respective steels is briefly indicated below.

17-4 P.H. Steel

Structure; behaviour in fusion welding; nature of the base-metal heat-affected zone, including freedom from cracking; underbead cracking (immunity of wrought material, susceptibility of the cast steel); notch-sensitivity and effect of notches in design; notch-sensitivity tests; remedial heat-treatments; low ductility of weld metal of 17-4 P.H. composition improved by compositional modification, resulting from metallographic study of structure.

17-7 P.H. Steel

Structure of the steel in the annealed condition; alternative hardening treatments for production of various levels of strength; hardening of cold-worked 17-7 P.H. Behaviour in fusion welding, with special reference to the influence of the aluminium present; inert-gas, metal-arc process most suitable; freedom from weld-metal cracking; weld-metal porosity due to aluminium nitride; correction by addition of titanium or zirconium. Characteristics of the base-metal heat-affected zone; post-weld treatments; weld metal for joining 17-7 P.H., including discussion of precipitation-hardening compositions suitable in metallic-arc welding with covered electrode and inert-gas tungsten-arc welding. Resistance welding; schedules for spot- and roller-seam welding; precautions required to ensure satisfactory welding properties.

17-10 P Steel

No completely successful method of fusion welding yet developed. Microstructure in relation to welding problems; use of flash-butt welded 17-10 P steel. Hot cracking a persistent problem in arc- and gas-welding; underbead hot cracking in heat-affected zone; report of preliminary laboratory investigation of this problem.

In closing, the lecturer referred briefly to observations made on the welding characteristics of experimental 17-10 P steels in which nickel is partially replaced by manganese or nitrogen. Some of these steels could be welded without occurrence of underbead cracking. In the steels so modified delta ferrite is formed in the weld-affected zone, and the hypothesis is advanced that delta ferrite has a higher solubility for phosphorus than has austenite, and thus prevents formation of the phosphorus-rich phase which in the normal 17-10 P steels promotes cracking. The presence of the delta ferrite has, however, the disadvantage that it interferes with the precipitation-hardening which should take place during the age-hardening treatment. It is suggested that this problem may be overcome by some modification of composition of the weld metal, thus making possible utilization of the beneficial influence of the delta ferrite in the parent steel.

Casting Properties of Nickel Alloys

See abstract on p. 55.

Gaseous Polishing of High-Alloy Steel

G. SCHMID, E. MAURER and H. STEINHAUSEN: 'Chemical Brightening of V-2A Steel with Gases.'
Metalloberfläche, 1956, vol. 10, Oct., pp. 289-95.

The authors describe experiments carried out in the University of Cologne, on the polishing of stainless steel by exposure to gaseous mixtures of various compositions. The work was prompted by the observation that in chemical polishing optimum brightening occurred just above the immersion line, i.e., in a region in which the atmosphere was gaseous.

Tests with various mixtures of nitric oxide, hydrogen chloride and steam indicated as optimum a composition of nitric oxide 30, hydrogen chloride 60, steam 10, mol. per cent. Oxygen or air was used as the carrier for introduction of the steam constituent. The best results were obtained by operating at a temperature of 50°C., for about 30 minutes.

Special apparatus devised for the tests is described, and detailed results of the experiments are recorded.

Corrosion by Fuming Nitric Acid

D. M. MASON: 'Properties of Fuming Nitric Acid Affecting its Storage and Use as a Rocket Propellant.'
Jet Propulsion, 1956, vol. 26, Sept., pp. 741-4.

The author discusses some of the general problems involved in storing fuming nitric acid in closed metal containers for periods of months, at temperatures in the region of 130°F. (55°C.). A survey is made of literature relating to properties which are of importance in connexion with the storage and use of the acid as a rocket propellant. Chemical methods of analysis are also discussed.

Two chemical processes which give rise to problems in the storage of this oxidant are:—

(1) The corrosion of metal containers, causing change in the composition of the acid and its contamination with metallic salts, and

(2) Thermal decomposition of acid which is low in NO_2 and H_2O, with resultant high pressures and changes in composition of the oxidant.

It has been found that liquid and gas-phase corrosion of aluminium alloys and of nickel-chromium stainless steels is markedly inhibited by the presence of about 0·5 per cent. by weight of hydrofluoric acid in the fuming nitric acid. Some typical results of corrosion tests on various steels and alloys are given, using fuming nitric acid with or without addition

of hydrofluoric acid. The mechanism of the passivation appears to be the formation of an impervious coating of insoluble metal fluoride on the surface of the metal. The second problem, that of thermal decomposition and correspondingly excessive storage pressures, is eliminated by the use of acid containing 12–16 wt. per cent. of NO_2 and 2–3·5 wt. per cent. of H_2O. Fuming nitric acid so modified and containing 0·5 per cent. of hydrofluoric acid has also other physical properties which render it suitable for use as a rocket propellant.

Corrosion by High-Purity Water

'Corrosion by High-Purity Water: A Symposium.' *Corrosion*, 1957, vol. 13, Jan., pp. 69t–85t.

The following papers were contributed to a symposium organized by the National Association of Corrosion Engineers in 1955.

J. F. ECKEL: 'Introduction to Symposium', p. 70t. Summary of the activities and objectives of the N.A.C.E. Committee on Corrosion by High-Purity Water, organized in 1952.

Advances in atomic energy have recently brought the subject of high-purity water into increasing prominence, but it is pointed out that it is also of wider significance, in relation to many chemical processes. For the purposes of the symposium 'high-purity water' is defined as 'water that has been distilled and/or de-ionized so that it will have a specific resistance of 500,000 ohm-cm. or greater before the addition of any soluble constituents'. This type of water is playing an important part in atomic-power development and there have already been extensive studies using it as the corrosive medium.

A. H. ROEBUCK, C. R. BREDEN and S. GREENBERG: 'Corrosion of Structural Materials in High-Purity Water', pp. 71t–4t.

The paper presents, in condensed form, a description of 'screening' corrosion tests carried out in the Reactor Engineering Division of the Argonne National Laboratory, Chicago, Ill.

The essential features of the apparatus and technique used are described and illustrated. The behaviour characteristic of representative groups of material are tabulated and a list is given of the individual alloys tested, on which the statements in the table are based.

It is emphasized that many operating factors influence the degree of corrosion-resistance offered by any given material, e.g., temperature, pressure, purity of water, concentration of dissolved gas(es), velocity of flow of water, etc. In addition, the behaviour of a material in high-purity water is affected by its surface condition and by the heat-treatment and mechanical working which it has undergone, also by degree of galvanic coupling, the geometry of the test sample, and the level of stress imposed upon the specimen. In the interests of space, discussion of these variables is restricted, in this paper, to the influence of surface condition, which is of major significance. In this connexion, the following comments are made:—

Treatments found to give the greatest resistance in high-temperature water were clean-machining and pickling. Overheating and/or surface slurring resulted in lessened resistance. Acid pickling also gave surfaces which had a good degree of corrosion-resistance. Selection of the pickling medium and technique was dependent upon the material being tested, but it is noted that a nitric acid–hydrofluoric acid pickle gave good results with many of the stainless steels and cobalt-base alloys.

Sand-blasting dulls and greys the surface and surfaces which had been thus treated showed a lowered degree of corrosion-resistance. Vapour blasting, whilst not so harmful as sand blasting, gives surfaces less resistant to corrosion than those finished by machining. Wire-brushing is recommended only for removing heavy scale or rust: such treatment results in high surface temperature, and worked metal in the surface, both of which factors are undesirable from the corrosion-resistance point of view.

Although it is noted that long-term corrosion exposure minimizes effects due to surface preparation, low initial corrosion-resistance may initiate other undesirable forms of attack such as pitting or cracking, and for this and other reasons the use of good surface preparation techniques is desirable.

D. J. DEPAUL: 'Corrosion Engineering Problems in High-Purity Water', pp. 75t–9t.

Commenting that the preceding paper has provided a good general picture of materials normally considered suitable for use in high-temperature water, the author supplements such information by dealing with corrosion problems which result from unexpected abnormal and transitory environments directly related to the engineering applications of individual materials. Among the conditions considered are crevice corrosion, galvanic corrosion, stress corrosion and intergranular corrosion. Most of the data presented are based on exposure to high-purity water at temperatures between 500° and 600°F. (260°–315°C.), and at velocities up to 30 feet per second.

The importance of crevice corrosion is urged, since it may produce relatively large amounts of corrosion product at the mouth of a crevice, and in applications involving moving parts having small clearances this may cause excessive wear or complete seizure. The mode of occurrence of this type of attack is illustrated by reference to a standard crevice-corrosion test specimen. A table summarizes the behaviour of typical materials in relation to crevice corrosion, and figures in the paper illustrate the influence of temperature, oxygen content of the water, and clearance, on susceptibility to this form of attack. Incidentally, warning is given, in connexion with crevice corrosion, of the undesirability of using 12 per cent. chromium steel (normally favoured as a rivet material), for rivets exposed in high-purity water at elevated temperature. Typical examples of crevice corrosion in such rivets

are described, also other cases of crevice corrosion, attributable to faulty design and/or material. It is noted that although the information presented in this paper on crevice corrosion is based solely on studies in high-purity water, there are indications that many of the observations made are applicable also to general industrial water systems, particularly boiler plants.

It has been found that, generally speaking, dissimilar metal contacts do not show evidence of preferentially accelerated corrosion in high-purity water: this immunity from susceptibility to galvanic corrosion is believed to be due to the high electrical resistivity of the water, which serves to interrupt any galvanic currents which might normally exist at a lower level of resistivity.

The investigation of stress corrosion reported by the author was concerned chiefly with finding spring materials suitable for working in contact with high-purity water. It was therefore a more or less ad-hoc study, in which only materials of potential value as springs were included, and these materials were tested only in conditions likely to be encountered in service. The tests were made on austenitic and ferritic stainless steels and on cobalt- and nickel-base alloys, including Inconel X, which latter material proved to be outstandingly suitable for springs operating in the conditions under consideration.

Supplementary tests on susceptibility to intergranular corrosion showed that high-purity waters are not sufficiently aggressive to cause such attack even in unstabilized chromium-nickel steel containing up to 0·25 per cent. carbon, in as-welded or sensitized conditions.

In discussion, J. E. DRALEY described the behaviour characteristic of aluminium and aluminium-base alloys in high-purity water. Although such materials are relatively satisfactory at temperatures up to 400°F. (205°C.), above that temperature severe blistering occurs and the metal is rapidly destroyed. Two remedial methods have been developed:

(1) provision of cathode sites for the liberation of hydrogen at positions other than the aluminium surface.

(2) making the aluminium impermeable to hydrogen diffusion.

In method 1, solutions of certain reducible metal ions can be used instead of distilled water, and among the reducible cations, those which produce metals of low hydrogen overvoltage are effective. Nickel sulphate is one of the usable media. Nickel metal deposits at preferred cathode sites on the aluminium and the hydrogen produced in the cathodic part of the corrosion reaction is liberated there. The concentration of nickel salt required is of the order of 5 p.p.m. It is necessary to add acid to such solutions, in order to prevent formation of basic salts and their deposition on heated surfaces.

The speaker referred also to alloys containing a small amount of nickel which have been found highly efficacious: the nickel-rich constituent appears largely as a second phase. Such materials satisfactorily resist blistering up to temperatures of about 600°F. (315°C.).

A further method, now under investigation, is plating the surface of the aluminium-base material with nickel. Promising results are being obtained on samples which have been coated by the Kanigen electroless method.

W. Z. FRIEND: 'The Importance of High-Purity Water Data to Industrial Application', pp. 81t–5t.

It is pointed out that most of the studies on high-purity water, especially those concerned with high-pressure elevated-temperature conditions, have been concerned specifically with the performance of materials of construction used in nuclear-power plants, in which the water serves as a combined coolant and heat-transfer medium. Most of the test conditions have involved temperatures of 500°–600°F. (260°–315°C.) and pressures up to 2,000 p.s.i. Some work has also been done at temperatures as low as 250°F. (120°C.).

The information on wear and corrosion obtained by such investigations has, however, a much wider significance, since water of high and controlled purity is essential to the efficient functioning of boiler plants and of equipment used in a large number of industries. A partial list is given of processes in which water of varying degrees of high purity is of major importance, and specific reference is made to the requirements for high-purity water in research laboratories, in production and use of television tubes, in plant processing pharmaceuticals, in the photographic and the pulp and paper industries, in preparation of ceramics for firing, in production of synthetic fibres, in electroplating installations, and in ice plants.

Some notes are added on satisfactory service experience with austenitic stainless steel, Inconel and Monel in contact with high-purity water, and reference is made also to the use of aluminium and aluminium-sprayed equipment. Data available on the behaviour of unalloyed steel in such service is somewhat contradictory: some typical experiences are summarized.

Reactions between Nickel and Sodium Hydroxide

See abstract on p. 50.

Stainless Steel/Plastic Light-Weight Train

'Stainless + Plastics Make Lightest Train Yet.'
Materials and Methods, 1957, vol. 45, Jan., p. 119.

By combining an all-stainless-steel structure with an interior built almost entirely of plastics, the Budd Company has produced a railway passenger coach which is claimed to have the lightest weight per passenger (595 lbs.) of any coach ever built in the U.S.A. This 88-passenger car is a basic design which can be adapted to nearly any type of passenger railway service. A seven-coach train of this type would show an overall saving in weight of nearly half a million pounds over other lightweight trains.

Austenitic Welding Electrode for High-Temperature Service

O. R. CARPENTER and R. D. WYLIE: '16-8-2 Cr-Ni-Mo for Welding Electrode.'

Metal Progress, 1956, vol. 70, Nov., pp. 65-73.

The authors discuss difficulties which have been encountered in high-temperature steam plant due to cracking of the welds and the heat-affected zones in austenitic steels of the 18-8 chromium-nickel type.

They describe experiments carried out to develop an improved electrode, giving details of tests used to determine the soundness and the mechanical properties of welds made with various 'modified' electrodes. The report includes illustrated notes on three test methods employed to assess the effect of weld restraint on the physical properties of the finished joint, also an account of long-time heating experiments for determination of susceptibility to sigma-phase embrittlement.

This work has resulted in development of a modified electrode containing chromium 16, nickel 8, molybdenum 2, per cent. which, under experimental examination, gave welds free from susceptibility to cracking. The joints showed satisfactory properties at high temperatures. The improved properties of electrodes of this modified type have already been confirmed in large-scale service, and this grade has been selected for welding 18-8 chromium-nickel steel components in a 4,500 p.s.i. boiler now being constructed in the U.S.A.

Electrodes for Welding of Clad Steels

See abstract on p. 57.

Hard Surfacing of Metals: Data Sheet

See abstract on p. 55.

Determination of Molybdenum in Steels

See abstract on p. 60

Determination of Cobalt in Nickel Alloys

See abstract on p. 58.

Production-Control Analysis in Steel Works

See abstract on p. 60.

PATENTS

Electrodeposition of Low-Stress Nickel

An aqueous electrolyte having good throwing power and producing deposits characterized by low stress contains a nickel salt (preferably nickel sulphate or nickel sulphamate) 3-4 oz./gal., sodium chloride or potassium chloride, present in 7-12 times by weight the amount of nickel content of the nickel salts, and boric acid up to 5 oz./gal. Cobalt (0·15-0·5 oz./gal.) may also be present. The solution is operated at a pH of 2-5: current density 15 amp./sq. ft. or above. Use of alternating current superimposed on direct current is also claimed, as a further means of reducing internal stress in the deposit.

S. A. VICKERS, LTD. (inventors, W. COWLE, D. E. MANSFIELD, P. SPIRO and G. C. WOOD).
Brit. Pat. 765,958.

Nickel-Coated Switch Contacts

Improved electrical switch contacts for use in weak-current apparatus (e.g., amplifiers and radio and television receivers) are made from nickel-coated stainless steel and such a contact may be used in conjunction with another plated contact or a unit made from nickel. The nickel coating is preferably 2-20μ thick and is produced by electrodeposition.

PHILIPS ELECTRICAL INDUSTRIES, LTD.
Brit. Pat. 767,479.

Electrodeposition of Nickel-Copper Alloys

Nickel-copper alloy deposits are obtained from a bath containing nickel ions, copper, cyanide (preferably sodium cyanide) and hydroxide. The preferred composition (g./L.) of the solution is:—nickel 5, copper 5, Na_3-P_3O_{10}10-200, NaCN 5-150, soda 10-150. A final coating of chromium may be superimposed on the nickel-copper alloy coating. The composition of the alloy can be varied by adjustment of the solution. Such coatings can be deposited on zinc-base as well as other materials.

TECHNI-METAL. *French Pat.* 1,127,495.

Deposition of Nickel and Chromium from the Carbonyls

Nickel and chromium are gas-plated onto steel via the respective carbonyls. Conditions are regulated to give a chromium coating 1-10 times the thickness of the nickel coating.

COMMONWEALTH ENGINEERING CO. OF OHIO.
U.S. Pat. 2,767,464.

Nickel Alloy in Composite Bearing Material

The patent relates to an improved form of composite bearing material of the type consisting of a backing of steel to which is bonded an interlayer consisting of a two-phase alloy (matrix of relatively hard metal, in which is dispersed a relatively soft metal) and a thin lining of a soft metal bonded to the interlayer. The interlayer of such composite frequently consists of copper or bronze in which lead is dispersed, or of silver.

This patent covers an improved composite in which nickel or a nickel alloy is used as the matrix of the interlayer and lead or lead alloy as its soft phase. Methods of applying the interlay are also covered. The nickel-lead alloy may also contain a small proportion of sulphide, to improve the bearing properties of the interlayer. When such layer is sintered in powder form onto the steel, the presence of the sulphide will facilitate sintering and bonding.

GLACIER METAL CO., LTD. (inventors, P. G. FORRESTER, W. E. DUCKWORTH and D. C. MITCHELL).
Brit. Pat. 767,259.

Nickel-Alloy Cathodes for Electron-Discharge Devices

Heater-cathode leakage, a major problem of the electron-tube industry, is kept to a minimum by the use, for the cathode, of a nickel alloy containing 0·23–12 per cent. (preferably about 2 per cent.) of chromium. The cathode is of the sleeve type: its design is illustrated and claimed.

SYLVANIA ELECTRIC PRODUCTS, INC.
Brit. Pat. 768,916.

Mischmetall Additions to Permanent-Magnet Alloys

Alnico magnets capable of being forged and rolled are made from an alloy to which cerium and/or lanthanum (0·16–0·81 per cent.) has been added. The material is hot worked to bar form, and is divided into the required lengths, thus obviating the need for separate casting of individual magnets. The addition alloy is preferably used in the form of Mischmetall. Niobium (0·5–3·25 per cent.) may also be present.

ENGLISH STEEL CORPN. LTD. (inventors, E. J. C. PATRICK, W. SORBY and G. W. ELLIS).
Brit. Pat. 766,791.

Ultra-High-Tensile Nickel-Alloy Steel

The following range of composition is claimed for a steel having especially high strength : weight ratio: carbon 0·35–0·45, silicon 1·3–2, manganese 0·5–1, nickel 1·5–3·5, chromium 0·7–1·5, molybdenum 0·1–0·5, aluminium 0·02–0·1, per cent., iron balance. Chromium+molybdenum is greater than 1 per cent. and vanadium up to 0·1 per cent. may also be present. The claims also cover heat-treatment, comprising heating at 1500°–1650°F. (815°–900°C.), cooling, and tempering at 400°–600°F. (205°–315°C.). Steels of such composition are particularly suitable for use in aircraft undercarriages.

MOND NICKEL CO., LTD. *Brit. Pat.* 766,090.

Complex Nickel-base High-Temperature Alloy

Vacuum-melted alloys for use at high temperatures contain chromium 19·5, cobalt 14·8, molybdenum 3·75, titanium 2·79, aluminium 2·94, per cent., nickel balance. Zirconium 2·5–2·75 per cent. may replace titanium.

UTICA DROP FORGE AND TOOL CORPN. (inventor, F. N. DARMARA).
French Pat. 1,128,868.
Italian Pat. 539,958.

Nickel-base Electrical-Resistance Alloys

Resistors for electronic and electrical instruments are made from alloys containing chromium 10–30, silicon 1·25–6, manganese 0·4–6 per cent., balance nickel. Silicon=0·4 (manganese+boron), the boron having a value between 0·6 and 4·8. Manganese may be partly or wholly replaced by copper, and up to 1 per cent. of one or more of the following metals may be present: calcium, magnesium, zirconium, boron, titanium, niobium, tantalum, vanadium. Typical examples are given as chromium 20, silicon 4·9, manganese 2·7, per cent., balance nickel, and chromium 19·3, silicon 3·8, copper 4·25, per cent., balance nickel. Such alloys are claimed to be characterized by improved specific electrical resistance and temperature coefficient, to have a high mechanical strength (especially in the range −50° to +250°C.) and to show high thermoelectromotive force against copper.

A. B. KANTHAL. *Brit. Pat.* 766,392.

Hard-Surfacing with Nickel Alloys

Metal components (e.g., valve seats) are hard-surfaced by placing a thin toroid of the coating metal on the seat, and subjecting this assembly to high pressure, while passing through it a heavy current, to cause fusion. Examples of coating alloys include nickel 60, chromium 16, molybdenum 17, tungsten 5, per cent. and nickel 80, chromium 10, boron 2, per cent. (remainder, small amounts of elements having less significant influence on the properties of the alloys), also cobalt-base and iron-base alloys.

EDWARD VALVES, INC. *Brit. Pat.* 767,435.

Production of Nickel-Alloy Powders

Powdered or granular metals are produced by adding boron to a metallic melt which is disintegrated and solidified, preferably by atomizing by means of a fluid under pressure. Examples of the process include the production of austenitic stainless-steel powder and the addition of nickel boride to a nickel-aluminium alloy.

DEUTSCHE EDELSTAHLWERKE A.G. (inventor, F. FREHN).
Brit. Pat. 767,429.

Corrosion-Resistant Spring Steel

Corrosion-resistant steel springs are produced from a nickel-chromium steel which after quench-annealing is austenitic and which after cold-working to a reduction of 50–70 per cent. contains 40–70 per cent. of martensite. The steel is tempered, after cold-working, at 400°–450°C. Preferred composition: carbon 0·07–0·2, nitrogen up to 0·1, chromium 14–20, manganese 0·4–2, silicon 0·2–2, molybdenum 0–4, nickel 7–12, cobalt 0–10, per cent., iron balance. Up to 1 per cent., each of the following elements may also be present: tungsten, titanium, niobium, tantalum, copper, vanadium and aluminium.

SANDVIKENS JERNVERKS A.B. *Brit. Pat.* 766,971.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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